United Nations Environment Programme

Distr.
GENERAL

UNEP/GC.16/9/Add.1
15 February 1991

ORIGINAL: ENGLISH

GOVERNING COUNCIL
Sixteenth session
Nairobi, 20-31 May 1991
Item 5 of the provisional agenda

# STATE-OF-THE-ENVIRONMENT REPORTS

# EMERGING ENVIRONMENTAL ISSUES

## Report of the Executive Director

## Summary

The present report consists of two main parts to reflect the request of the Governing Council in its decision 15/13 B: the first part covers the issue of new technologies, the emerging environmental issue selected for more detailed elaboration by the Governing Council; the second comprises a brief description of the issues of municipal waste (focusing primarily on liquid waste, as municipal solid waste was dealt with in document UNEP/GC.14/9), plastics and the ecological situation in the Arctic.

## Suggested action by the Governing Council

The Governing Council may wish to:

1. Take note of the present report of the Executive Director on emerging environmental issues;

2. Request the Executive Director to bring to the attention of all Governments the emerging issues included in the present report;

3. Further request the Executive Director:

   (a) To continue to review the environmental impacts of new technologies; and

   (b) To include in his report on the State of the Environment 1993 a detailed examination of two of the following emerging issues:

      (i) Re-use of wastewater;

      (ii) Volatile organic compounds in air;

      (iii) Tropospheric ozone; and

      (iv) The ecological situation in the Antarctic.

## INTRODUCTION

1. The General Assembly in resolution 2997 (XXVII) of 15 December 1972 decided that the Governing Council of the United Nations Environment Programme should "keep under review the world environmental situation in order to ensure that emerging environmental problems of wide international significance receive appropriate and adequate consideration by Governments."

2. In decision 10/1, section II, the Governing Council requested the Executive Director to supplement the annual state-of-the-environment report with a section focusing on the most important environmental events and emerging issues.

3. In its decision 12/3 B, the Council requested the Executive Director to "update the list of emerging issues for each session of the Governing Council ...".

4. In its decision 15/13, the Governing Council decided that a detailed elaboration of the issue of new technologies and a brief description of the issues of municipal wastes, plastics and the ecological situation in the Arctic should be presented in the Executive Director's report on emerging environmental issues, to be submitted to the Council at its sixteenth session.

## I. NEW TECHNOLOGIES

5. Significant scientific advances during recent decades have opened the doors for new developments in several areas. Furthermore, industry has taken these advances seriously, and many have found their way from research laboratories to industrial plants at a pace that has taken society by surprise. In some cases, legislators and administrators have found themselves confronted by issues never dealt with before.

6. New technologies, like almost everything, bring benefits and drawbacks. Industry works to maximize the benefits and minimize the drawbacks, in order to make its products acceptable to society, but it is up to society to decide whether it is ready to accept the drawbacks, if any, in exchange for the benefits. By identifying and analyzing the risks, science can help to provide the basis for an informed decision.

7. One of the best examples of a new technology that is evolving at a very rapid pace is biotechnology. Although biotechnology has been used by man for centuries (fermentation for bread or wine, selective breeding of livestock, hybridization of crop plants, etc.), a major breakthrough in 1973, the recombinant DNA technique, triggered a new revolution by making it possible to jump over the barriers between species imposed by nature and transfer genes among different species, genera and even kingdoms. (1)

8. When applied to the higher animals and plants, biotechnology can bring great time savings in selective breeding by directly transferring the gene that confers the desired characteristic: for example, in plants, resistance to low temperatures or to high salinity; and in the case of animals, better adaptation to harsh environments, such as dry or hilly regions. (2)

9. The higher organisms are relatively easy to monitor and control. They are visible to the naked eye and could be contained if necessary, so as to avoid undesirable proliferation. Biotechnology can even produce one-crop seeds that give rise to plants whose seeds cannot germinate. This is, perhaps, the reason why biotechnology has been better accepted in animal husbandry and plant improvement. However, the introduction of exotic

species of plants and animals has already had negative effects. More than a hundred introduced species have been declared harmful in Australia. (3)

10. It is also worth noting the impact that biotechnology may have on the genetic diversity of the planet. On the one hand, it offers powerful techniques for quicker germplasm identification, better storage of genetic resources and accelerated plant breeding. On the other hand, a technique known as tissue culture, which allows the reproduction of plants from single cells or tissues, could have a serious negative impact. (4)

11. When biotechnology is applied to micro-organisms, whose interactions among themselves and with the external environment are not so well known, special precautions have to be taken.

12. In a broad sense, genetically engineered micro-organisms can be utilized in two ways: the first of these involves the recovery of products metabolized by the micro-organisms; the other focuses on the action of these micro-organisms on a particular environment. The first type of process makes use of reactors in which the micro-organisms act on a controlled environment and the sought-after product is recovered. Examples of this kind of process are found in the production of antibiotics, insulin, human growth hormone, and in the production of chemicals, food and feedstuff. Although the reactor itself is a primary containment element, this type of process presents risks for people within the working environment and outside the industrial installation at the laboratory and pilot plant stage, in industrial processing and by-product handling, and risks associated with the products obtained. (2)

13. The second way to utilize genetically engineered micro-organisms entails the release of such micro-organisms into the environment with different levels of control. Examples of this type of process are found in waste management (digestion of wastewater in a somewhat controlled environment, digestion of PCB's), clean-up operations (digestion of spilled oil and soil-diffused pollutants), use as biological pesticides (outside or within the crops, through symbiotic micro-organisms), extraction of metals from mine ore, desulphuration of coal, etc.

14. This second method is obviously riskier, because there is no complete control over the organisms involved. Very little is known about the behaviour of micro-organisms in the external environment. The introduction of a genetically manipulated organism into the environment poses a number of questions that cannot be answered with certainty: will the organism survive? Will it multiply? Will it disturb fundamental ecosystem processes? Will the inserted genetic material be transferred to other organisms? Will the organism be transported to unintended sites? (5) These are some of the questions. The myxomatosis epidemic in Europe since the fifties may be an example of a "too successful" micro-organism intentionally released into the environment and it shows that adverse environmental impacts can spread across national boundaries, thus becoming the subject of international or even global concern.

15. One thing that seems to be certain is that a particular micro-organism is or is not harmful in itself, and this does not depend on the technique employed for its creation, be it genetic engineering, mutation by irradiation or ultra violet light or any other means. While, during the eighties, focus was put on the process of biotechnology itself, in the present decade the focus may shift to the products of biotechnology instead. (1,2)

16. There are other, so-called new technologies which, despite their important advantages, have proven to have serious environmental impacts. The development and introduction of new materials (composites, engineered plastics, etc.) has led to lighter and more efficient means of

construction, but not without side effects. In the last two decades, the amount of plastic materials used in the production of automobiles in the United States of America, for instance, has increased from an average of 50 kilogrammes per unit to 125 kilogrammes per unit, or roughly eight per cent of the weight, (6) and this proportion is expected to reach between 15 and 20 per cent by the year 2000. (7)

17. While the consequent decrease in automobile weight has an obvious favourable impact in terms of fuel savings (and fuel is a non-renewable resource), the increasing amount of a scrap vehicle that is not easily recoverable and, accordingly, the increasing cost of disposing of this material could disrupt the operations of car salvage dealers. The performance of a recycling industry that today recovers more than 80 per cent of the ferrous metals and aluminium and more than 66 per cent of the copper content of scrap automobiles in the United States (6) could be jeopardized.

18. New degradable plastics promise to solve at least some of the problems associated with the widespread use of plastics and plastic composites, but they pose other problems too. The presence of degradable plastics in the waste stream could undermine the present efforts to recycle plastics. (8) In addition, techniques using oxidizing agents such as starch, one of the approaches being followed, result only in the physical degradation of the plastic. The material becomes porous and brittle and after 10 years the resulting fragments are too small to see with the naked eye, (8) but such a process could lead to a mere shift from localized to diffuse pollution.

19. Information and communications technology is yet another example of technology with an expected impact on the environment. It was predicted that the advent of computers would reduce paper use and wastage, but printouts of data and hard copies of documents have become the rule rather than the exception, perhaps through fear that electronically stored records may not have the two- or three-hundred-year lifespan of good paper. (8)

20. Computers and photocopiers work together in the development of huge mailing systems that would once have been unthinkable. In 1959, a consulting company estimated that 5,000 photocopiers would saturate the market in the United States. In 1986, business in that country bought 200,000 of these machines. (8) The latest massive introduction, the facsimile machine, has resulted in a new flood of high-quality paper around the world, and the expected price reductions will make the flood increase.

## II. PLASTICS, MUNICIPAL WASTES AND THE ECOLOGICAL SITUATION IN THE ARCTIC

### Plastics

21. Since they were first produced commercially in 1868, plastics have found their way into almost every aspect of everyday life. In the United States alone, some 25 million tonnes of plastics were produced in 1988, (9) with an average annual growth rate of 10 per cent over the last 30 years. Continued growth is expected, owing to the many advantages plastics offer over other, more traditional materials: design flexibility, high resistance to corrosion, low weight and shatter resistance. (10)

22. The impacts of a plastic on the environment are different throughout its life cycle: production, working life and disposal. Production of plastics entails the use of non-renewable resources, mainly petroleum and natural gas, as raw materials for the synthesis of the necessary petrochemicals. Nevertheless, two main points should be highlighted in this context:

(a) The proportion of petroleum and natural gas employed in the production of petrochemicals is quite small compared to the amount used as fuel and in other industrial processes such as production of asphalt, lubricants, etc. It accounts for only 2 per cent of the total carbon base in the United States; (9)

(b) When the properties of plastics are fully exploited, the balance in terms of natural resource consumption can be favourable to them. For example, although the production of plastics uses roughly two kilogrammes of crude oil equivalent per kilogramme of polymer, one kilogramme of milled steel uses 1.1 kilogrammes of crude oil equivalent. (7) Break-even point is reached when plastic products are used which weigh about half their steel equivalents.

23. The environmental impact of a plastic during its working life is almost negligible. Plastics are basically inert, and consequently their interaction with the environment is minimal. Moreover, some applications of plastics lead to savings in other environmentally sensitive materials such as timber for building, animal furs for clothing, etc.

24. The last stage in the life cycle of plastics is their disposal. At this point, several of the characteristics that make them attractive become serious disadvantages: their low density means buoyancy, high resistance to corrosion means long-life waste, and shatter resistance means slow physical degradation. The impacts of disposal of plastics are different on land and at sea.

25. As far as disposal on land is concerned, the main concern is the huge amount of plastic wastes produced. In the United States over 10 million tonnes of plastic wastes are generated every year (9) and this figure is expected to increase by 50 per cent by the year 2000. (10) In the European Community the figure is roughly the same; (11) Japan annually generates over two million tonnes of industrial plastic waste. (12) Plastic residues constitute 14 to 21 percent of the total volume of the municipal waste stream in the United States. (10) The enormous amounts contribute significantly to the growing problem of lack of appropriate landfill space.

26. When incineration is used as a method of disposal, plastics contribute significantly to the heating value of municipal solid waste. However, there is controversy over whether some plastics contribute to emissions of harmful pollutants from municipal waste incinerators. (10) This applies mainly to chlorinated plastics which should be replaced by less harmful materials, such as PE or PET. PVC film could be a candidate for immediate action in this respect.

27. The impact of plastics at sea is very serious. Most plastics float and, together with the non-degradability, this leads to the very long life of plastic debris on the sea surface and shoreline. More than 80 per cent of the debris sighted at sea has been found to be plastic. (13) Nearly four per cent of all refuse that is discharged into the seas consists of plastic, amounting to about one million tons per year. (9) Plastics find their way to the sea from both land- and marine-based sources. Sewer overflows or direct sewer discharge, plastic manufacture and related transportation activities and stormwater runoff are the main land-based sources. (10) Shipping (fishing boats, and cargo and recreational vessels) and offshore oil and gas platforms are the main marine-based sources. (9,10)

28. The main impact of such plastic wastes is borne by marine life. It is estimated that lost fishing nets, traps and lines, dumped plastic ring-carriers for beverage cans, plastic pellets, bags, etc., kill millions of marine vertebrates every year, either through entanglement or ingestion. Plastic particles are mistakenly ingested by numerous seabirds, mammals,

turtles and fish. In addition to obstructing digestive tracts, plastic particles cause ulceration and often starvation. (13) "Ghost nets", lost or discarded nets or net fragments, can continue to catch fish for years. Over 1,000 kilometres of net are lost each fishing season in the North Pacific alone, (13) causing the death of more than one million birds and 100,000 sea turtles and marine mammals every year. (9) Moreover, plastic wastes that are washed ashore are unsightly and damage recreational use and the tourist trade at beaches and scenic areas.

29. One way to improve the situation would be for the Parties to the International Convention for the Prevention of Pollution from Ships to ensure the strict application of its annex V (on prevention of pollution by garbage from ships).

30. Another possibility of mitigating the impacts of plastic wastes lies in recycling. In this respect, it is worth noting the efforts under way:

(a) Recycling of monopolymeric wastes. This is the most economically efficient plastic recycling process in terms of the final product. The plastic waste is sorted and the selected resin cleaned and reprocessed. There are restrictions, however, on the use of these recycled plastics; (9,11)

(b) Recycling of mixed plastics. An unsorted mixture of plastic waste, with some limitations on the proportions of the different components and of impurities, is directly converted into different items by different moulding processes, to produce plastic lumber (for roadside markings, fence posts, picnic tables, etc.), plastic building panels, plastic flooring planks, plastic pavements, etc.; (9,11)

(c) Depolymerization of plastic waste. This technology is to recover the petrochemical components of plastics that can later be made into virgin resins. The technique is not widespread as yet, but might be useful should the supply of petrochemicals become limited or comparatively expensive. (9)

31. Programmes for the sorting of household waste, and of plastic wastes in particular, would effectively improve the economics of the above-mentioned recycling processes. Programmes of this nature are already being implemented in several countries. (9,11) In all, recycling of plastic wastes is not widely practiced. In the United States, for instance, the proportion of recycling is about 1 per cent of the consumers' plastic waste. (10) If countries were to adopt new regulatory approaches and an improvement in the recycling process and if there were increased public concern, the proportion of recycled plastics could be increased. There should be an effort to reduce the amount of plastics used in packaging, for example, together with consumer education about proper use and disposal of plastics in order to minimize wasteful habits and foster appropriate disposal practices, rather than careless littering.

32. Recovering the energy content of plastics can help to reduce the burden on landfills and, at the same time, prevent this energy from being lost. Several technologies (incineration with energy recovery, pyrolysis, hydrogenation) are available or being developed to this end. (7,9,11)

Liquid Municipal wastes

33. Wastewater from cities discharges micro-organisms, suspended solids, organic matter, toxins from industrial processes and other pollutants into the bodies of water it reaches. Pathogenic micro-organisms are of particular concern in terms of human health, mainly in cases where, due to lack of purification facilities, they may enter the drinking water supply. In the developing world, 40 per cent of deaths are caused by infectious and parasitic diseases, many of which are water-borne. (14)

34. Sewage, when released untreated, is one of the major causes of freshwater pollution in the developing countries. In Pakistan, the amount of municipal sewage is four times as great as the amount of wastes emitted by the industrial sector, and most of it is directly discharged into rivers. Sewage discharges from Colombo (Sri Lanka) contributes to organic pollution in the Kelani River, where coliform levels are over 68,000 per 100 millilitres. (15) Even in some countries where most sewage is treated, recent measurements of fecal coliforms indicate increasing pollution. Domestic wastewater also contributes to the load of nutrients of the recipient bodies of water, and is one of the causes of eutrophication. (16)

35. Treatment of municipal liquid wastes is closely related to the availability of sanitation systems. It is virtually impossible to implement any successful strategy for dealing with this type of waste without the previous existence of a collecting network. Although in 1980 the United Nations launched the International Drinking Water Supply and Sanitation Decade with the slogan "clean water and sanitation for all by the year 1990," that goal is still far from being achieved. In 1985, sanitation services in the developing world, excluding China, were available for about 60 per cent of the urban population and less than 20 per cent of the rural population. (17)

36. The conventional solution to the problem of sanitation in metropolitan cities is the provision of sewerage and sewage treatment. However, bearing in mind the cost of conventional sewerage and the high incidence of excreta-related diseases in developing countries, programmes that focus on alternative sanitation technologies, which are simpler and cheaper, as well as socially acceptable, could achieve the aim of improving public health without imposing an excessive financial burden.

37. Once the wastewater has been collected, treatment and appropriate disposal can start. Even in the developed world, sewage treatment is not as widely undertaken as is commonly thought. The proportion of the population actually connected to a treatment plant falls to below 50 per cent in countries such as Belgium, Italy, Japan, New Zealand and others. (18) In the developing world, the situation is even worse. In New Delhi, more than 240,000 cubic metres of liquid waste are produced every day and more than half of this flows into the Yamuna River, heavily polluted, without even primary treatment. (19)

38. There are several wastewater treatment processes that can be used. Traditionally, they have been divided into three main categories:

(a) Primary treatment: This treatment includes plain or chemically assisted settling of the wastewater and removes much of the suspended solids. It cuts the biological oxygen demand by 20-30 per cent and can remove up to 99 per cent of bacteria; (20,21)

(b) Secondary treatment: This depends on biological processes to reduce suspended solids, cut the biological oxygen demand by 80 to 90 per cent and reduce the bacteria present in the raw wastewater by a proportion that ranges from 99 per cent (in the case of activated sludge, biofiltration or aerated lagoons) to over 99.99 per cent (in the case of waste stabilization ponds); (18,21)

(c) Tertiary treatment: Chemical processes are directed toward specific target pollutants: nitrogen, phosphorous, etc. (20)

39. Waste stabilization ponds have been found to be a low-cost method of wastewaster treatment in developing countries where suitable land is available at a reasonable cost. A series of small ponds provides the most efficient design. (20)

40. The discharging of effluent from wastewater treatment facilities into bodies of water must take into account their self-purification capacity. If the waste load exceeds the limit, anaerobic decomposition will take place, giving rise to unsightly, malodorous and health-threatening conditions.

41. Final disposal of raw and stabilized sludges and other residues from treatment facilities usually involves some form of disposal on land. Controlled landfilling is the best method to dispose of sludge, grease, grit and other solids. By covering the newly deposited wastes with fresh soil daily, nuisances such as odours and flies can be minimized. Re-use of sludge as a soil conditioner and fertilizer is also an attractive possibility, provided the product can be economically marketed.

42. Wastewater, after appropriate treatment, can be reclaimed for irrigation, reducing the need for fertilizers, or used in aquaculture. There are a number of successful examples of this practice all over the world, in both developed and developing countries, including Australia, China, Germany, India and Mexico. (21)

Ecological situation in the Arctic

43. The Arctic is not an easily definable geographic feature of the Earth. There are several definitions, according to the characteristic most relevant for various disciplines. The Geographical Arctic is the area north of the Arctic Circle, latitude 66 degrees 32 minutes north; the Meteorological Arctic is defined as the area north of the 10-degrees-centigrade summer isotherm. However, for environmental purposes it is perhaps most appropriate to define the Arctic as the portion of land and sea situated north of the "tree-line", this is the limit beyond which trees do not grow. (22)

44. The Arctic is home to very specialized flora and fauna. Arctic flora forms a characteristic biome known as tundra, composed of many different species of shrubs and grasses. Many Arctic animals and plants are circumpolar in distribution, inhabiting the northern tips of three continents, Europe, Asia and America, very close at this latitude and under very similar ecological conditions. American caribou and Eurasian reindeer, for example, belong to the same species and serve as a basic resource for native peoples in north America, Scandinavia and Siberia, either through hunting or herding. (22,23) In addition, the Arctic is very important as a temporary habitat for non-resident creatures. It is the breeding ground for nearly one-sixth of the birds of the northern hemisphere. (14)

45. The Arctic has served as a refuge for species that have been decimated in other parts of the world due to human encroachment on their habitats or to their special sensitivity to pollutants. This has been the case, for instance, with the American bald eagle, which was nearly eliminated from the United States by DDT pollution, but whose Arctic population has remained quite stable. (23)

46. Among the Arctic vegetation, lichens are of particular importance from an environmental point of view. Their slow growth causes them to concentrate airborne pollutants effectively. Most lichens disappear from areas where there is sulphur pollution. Lichens also tend to concentrate radioactive fallout, as was the case during the 1950s, when atmospheric nuclear testing was still being carried out, and again as a result of the accident at Chernobyl. (23) Therefore, lichens may serve as a biological indicator of the status of the Arctic environment.

47. The part of the Arctic Ocean which is underlaid by continental shelves is one of the world's richest fishing grounds, yielding about a tenth of the annual global catch. Over three-quarters of a million whales, seals and other marine mammals enter Arctic waters in summer. (14) The impact of the fishing industry on the Arctic ecosystem and, in particular, on non-target species is a matter of concern.

48. The time of massive fur seal hunting and widespread whaling has passed, taking with it the great auk, the Labrador duck and Steller's sea cow, among others. Now the exploitation of the Arctic's resources together with atmospheric and marine pollution are the main threats to the ecological balance of the region. More than two-thirds of the USSR's gas reserves, a quarter of the United States' oil supply and unknown reserves in Canada lie north of the Arctic Circle. The Arctic also holds vast deposits of different minerals. The exploitation of these resources without appropriate consideration for environmental factors could lead to irreparable damage. (14)

49. Biological processes take place very slowly in the low temperatures of the Arctic, its biomass production is, on average, about 1 per cent of that of the temperate zones. (14) For this reason, damage caused to its environment may take a long time to recover. In this respect, the "Exxon Valdez" oil spill in the sub-Arctic region is a lesson on how disastrous an incident at high latitudes may be. Critical ecosystems in the region, both terrestrial and marine, should be identified in order to ensure their sound management and establish protected representative samples to preserve the maximum diversity of wildlife and habitats.

50. Fortunately, the process of protecting the Arctic is under way. The eight Arctic countries: Canada, Denmark, Finland, Iceland, Norway, Sweden, the United States and the USSR, have developed a programme for protecting the Arctic environment. The programme activities include the preparation of reports on the impact of various forms of pollution, ranging from acidification to radioactivity. Preparations for the drafting of an Arctic Sustainable Development Strategy, an Arctic Environmental Protection Strategy and environmental monitoring of the Arctic, among others, have also been undertaken within the programme. (24) The Agreement on Conservation of Polar Bears, signed in Oslo in 1973 and in force since 1976, is another example of environmental co-operation among Arctic countries: Canada, Denmark, Norway, the United States and the USSR committed themselves to the protection of this emblematic Arctic species through joint and co-ordinated research and management and information exchange. Other international agreements among Arctic States could be concluded under the Convention on the Conservation of Migratory Species of Wild Animals, to provide for joint research and conservation measures for endangered migratory Arctic species which require international co-operation for their conservation.

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United Nations Environment Programme

EP

Distr.
GENERAL

UNEP/GC.16/9/Add.2
18 February 1991

ORIGINAL: ENGLISH

GOVERNING COUNCIL
Sixteenth session
Nairobi, 20-31 May 1991
Item 5 of the provisional agenda

# STATE-OF-THE-ENVIRONMENT REPORTS

## Hazardous environmental events

## Report of the Executive Director

The Governing Council in its decision 11/1, section II, requested the Executive Director to include a description and analysis of any exceptional major environmental events in his annual state-of-the-environment reports. The Executive Director has consequently reported to the Governing Council on such issues. The present report describes the major hazardous environmental events that occurred from January 1989 to January 1991.

## Suggested action by the Governing Council

The Governing Council may wish to:

1. Take note of the report of the Executive Director on hazardous environmental events;

2. Request the Executive Director to bring to the attention of all Governments the events described in this report;

3. Further request the Executive Director to keep under review the different environmental events and to report to the Governing Council at its seventeenth session in 1993 on any major events that may occur.

## ALASKA OIL SPILL

1. On March 24, 1989, the supertanker "Exxon Valdez" ran aground on Bligh Reef, Prince William Sound (Alaska), spilling over 38 million litres of crude oil into this highly environmentally sensitive area. (1)

2. The "Exxon Valdez" is a single skin tanker, roughly 300 metres long, 50 metres wide and 27 metres deep. Its deadweight is 213,755 tons and at the time of the grounding it was loaded with some 200 million litres of crude oil from Prudhoe Bay (Alaska North Slope) that had been pumped to the Alyeska marine terminal in Valdez through the trans-Alaska pipeline. (1)

3. Prince William Sound is one of the largest tidal estuarine systems on the North American continent and much of its area was largely pristine until the "Exxon Valdez" incident. It is an area of great natural beauty, and its relative accessibility makes it a favourite location for local recreation. Its rich natural resources form the basis for major commercial fisheries for pink and chum salmon and Pacific herring, as well as smaller fisheries for other species of fish and crustacea. It is also home to seals, sea otters and several species of whale. (1)

4. The location of Prince William Sound in the sub-Arctic region adversely affects the natural ability of the environment to regenerate itself. Low temperatures mean that oil is physically and biologically degraded at slower rates than in temperate zones. In addition, the physical features of the shoreline and its remoteness are added difficulties for clean-up operations. (1)

5. Together, the above-mentioned circumstances led to the worst oil spill in the history of the United States of America (1), and maybe in the world in terms of ecological damage, although globally the accident ranks only tenth in terms of the amount of oil spilled. (2)

6. The response to the spill was directed towards two goals: to prevent additional oil leaking from the damaged vessel, and to protect environmentally sensitive areas. The first goal was satisfactorily achieved through the transfer of the remaining oil to the "Exxon Baton Rouge", "Exxon San Francisco" and "Exxon Baytown" without any significant additional spills. (1) However, the protection of sensitive areas at an early stage was hindered by several factors.

7. Although the contingency plan prepared by the Alyeska terminal covers scenarios including the spill of about 31 million litres of oil, the equipment located at the terminal was not sufficient to cope with a spill of such magnitude. The response barge had been stripped of equipment, the quantity and size of containment boom was insufficient and there was a shortage of personnel. (1) In addition, during the first 24 hours few skimmers were working in the area, and those that were working did not have the possibility of transferring recovered oil to a receiving barge. (1)

8. As days passed following the accident, more and more personnel and equipment were transported to the area. On April 1, over one hundred vessels were operating in the area, 800 Exxon personnel, and over one hundred federal personnel. On April 13 these numbers had increased up to 250 vessels, almost 2,000 Exxon personnel and 500 federal personnel. As of April 10, Exxon had flown in over 1,700 tons of equipment. (1) When beach clean-up operations reached their maximum extent, more than 10,000 individuals were involved in the operations. (3)

9. The clean-up methods used to remove oil from the water surface comprised application of chemical dispersants, on-site burning and mechanical recovery. (1) The use of dispersants was not very successful due to the adverse weather conditions. During the first two days, the water was too calm to facilitate the proper mixing of the oil and the dispersant. Later, gale-force winds moved the oil to areas where the use of dispersants was not recommended. (1)

10. Burning was not widely used. In fact, only one test burning was performed with controversial results due to reports of eye and throat irritation from residents in the vicinity of the test site. (1) Nevertheless, from a technical point of view the controlled burning was quite a success, with an estimated

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efficiency of more than 98 per cent in removing from the water the 55,000-110,000 litres of oil burnt. (4)

11. Mechanical recovery was the preferred method because it removes oil without possible environmental effects. However, the distances involved brought considerable delays and difficulties in the transport and operation of skimmers and sorbent booms. The total amount of oil recovered from the sea was less than 3 million litres.

12. About 1,400 kilometres of shoreline within Prince William Sound were affected by the spill. The methods employed to clean-up this shoreline have been: high- and low-pressure water spraying, sorbent booms, manual removal and, at a later stage, enhancing of natural biodegradation processes. (1, 3)

13. The first three of the clean-up techniques mentioned-above are widely known, but the enhancing of biodegradation processes had never before been undertaken on such a scale. A co-operative agreement between the United States Environmental Protection Agency's Office of Research and Development and Exxon was the basis for launching a study to test the performance of bioremediation in treating contaminated beaches in Prince William Sound: the Alaskan Oil Spill Bioremediation Project. The core idea was to enhance the activity of micro-organisms that degrade oil, by making available to them the nutrients necessary for their growth (namely, nitrogen and phosphorous), which do not occur in the appropriate quantities in an oil-rich environment, by means of on-site application of fertilizers. (3) The results of the tests were highly promising in terms of effectiveness and lack of adverse environmental impacts, although more research is still necessary. (3)

14. The effects of the oil spill on the Prince William Sound ecosystem can be considered as twofold: an immediate impact, and a long-term impact. The immediate impact on some groups is as follows:

(a) The oil slick can adversely affect plankton, through either suffocation or toxic effects. As plankton includes floating eggs and larvae, long-term populations of fish, molluscs and crustacea, as well as algae may also be affected; (1, 3)

(b) Oil present in the surface or in the water column can find its way into the insulating fur coat of sea otters, leading to loss of buoyancy and hypothermia, or into the feathers of marine birds, disabling them. It may also be ingested, with toxic effects. (1, 3, 5) Tens of thousands of marine birds and almost one thousand sea otters have been reported dead, but the actual toll could be much higher; (6)

(c) Intertidal animals, such as barnacles and mussels, have little or no mobility. Oil in intertidal areas can therefore cause severe mortality among these animals; (1)

(d) Through the trophic chain or through their gills, fish can absorb chemicals that may have toxic effects and also impair swimming ability, making them vulnerable to predators; (5)

(e) Terrestrial animals, such as river otters, mink, bald eagles and deer, can also suffer an indirect impact by scavenging oil carcasses or browsing on oiled kelp. (1) In the summer following the accident, bald eagle productivity was 16 eaglets for every 100 nests in the oiled area, compared with 49 eaglets for every 100 nests in a non-affected area. (6)

15. Long-term impacts are still being evaluated, but they may arise primarily from habitat and food chain disruption, as well as the decreased survivability and reproduction rates of animals exposed to the oil. These effects, while perhaps not immediately fatal to a given individual, have a direct bearing on the survival of the species as a whole and consequently on the ecosystem of which it is a member. (1, 3) Another factor can contribute to the long-lasting effect of the spill: the oil present in low-energy areas (areas exposed to low to moderate wave energy and/or tidal currents) may remain present for years with only slow chemical and biological processes to degrade it, serving as a reservoir for a chronic input of oil into subtidal sediments, where it may affect benthic organisms over the long term. (1) In this respect, the efforts under the Alaskan Oil Spill Bioremediation Project may be of great importance, given the possibility of using this technique to ameliorate surface and subsurface oil biodegradation. (3)

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